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(54) Electronic displays

(57) A monochrome or multicoloured display e.g. for an outdoor scoreboard comprises a large number of light source elements, each having a compact array of LEDs. Each element can emit light of sufficient luminance to be seen in direct sunlight. For full colour display each element has a cathode 30 and three anodes 130, 136 and 170, for the illumination of sets of red, green and blue LEDs 120, 122 and 162, respectively. Selective illumination of these sets can be used to generate any colour in the spectrum. The LEDs in each array may be combined in parallel, series-parallel, or series to form the array. Each element may enclose the LED array in a lamp like structure so as to replace lamps in a conventional display. Several elements may be formed as a matrix on a large board and selectively accessed to form a pattern or message. A concave reflector may be associated with each LED.

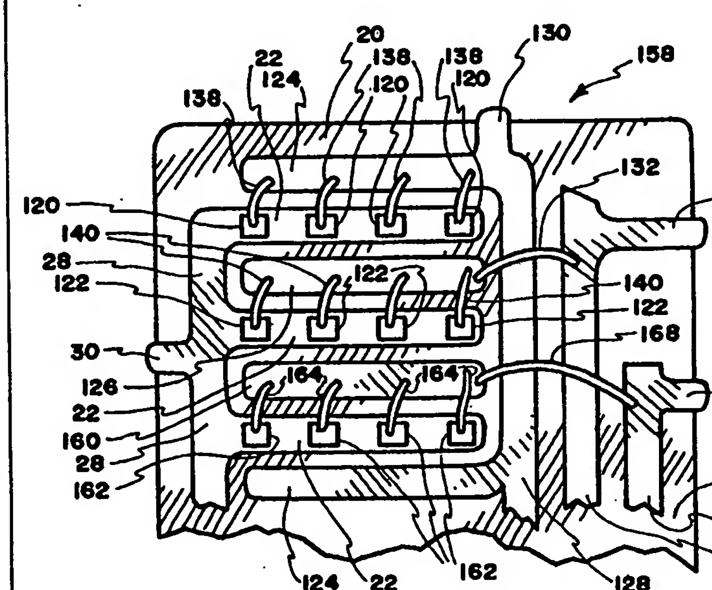

Fig. 6

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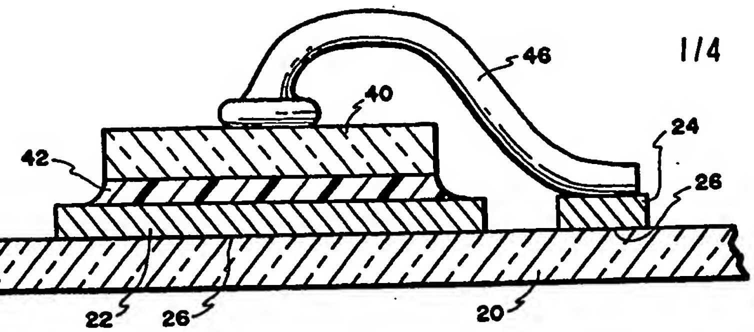
Fig.1



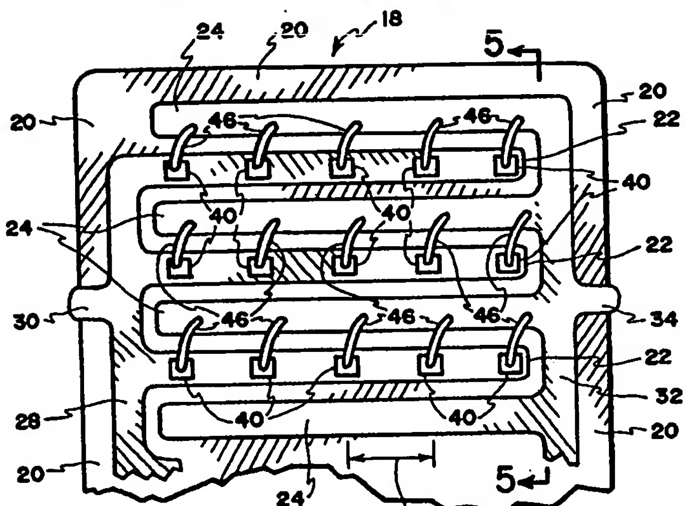


Fig.4

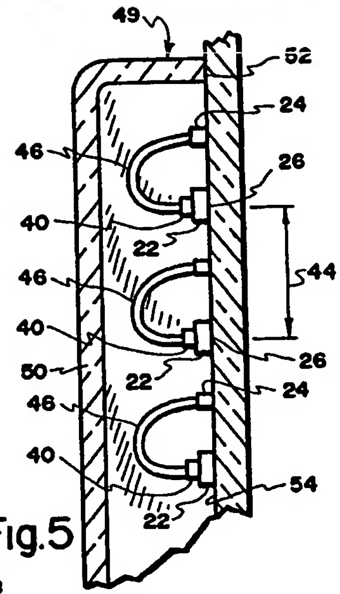


Fig.5

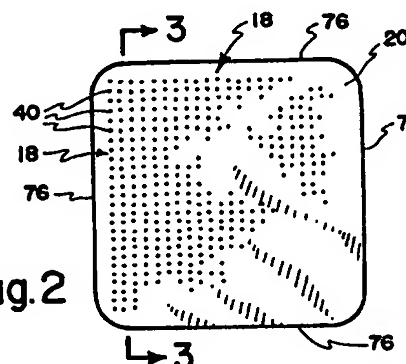


Fig.2

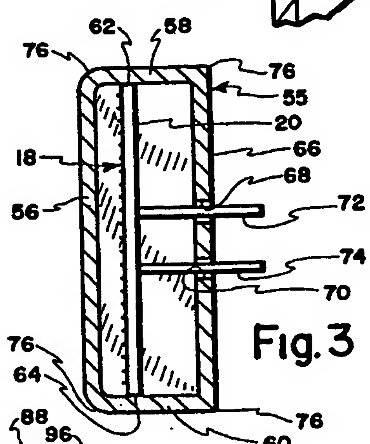


Fig.3

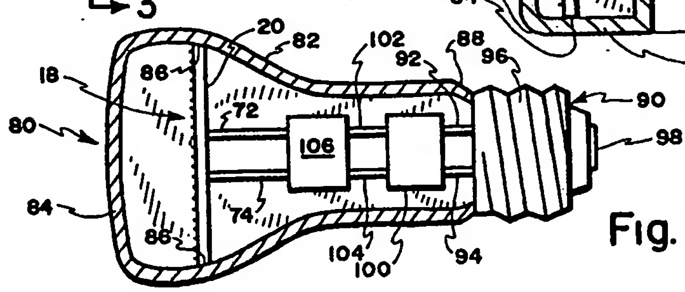


Fig.14

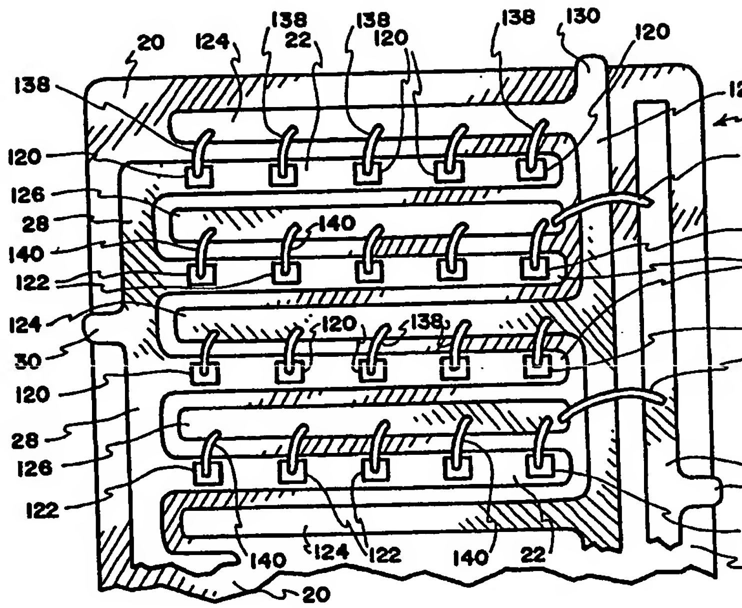


Fig. 7

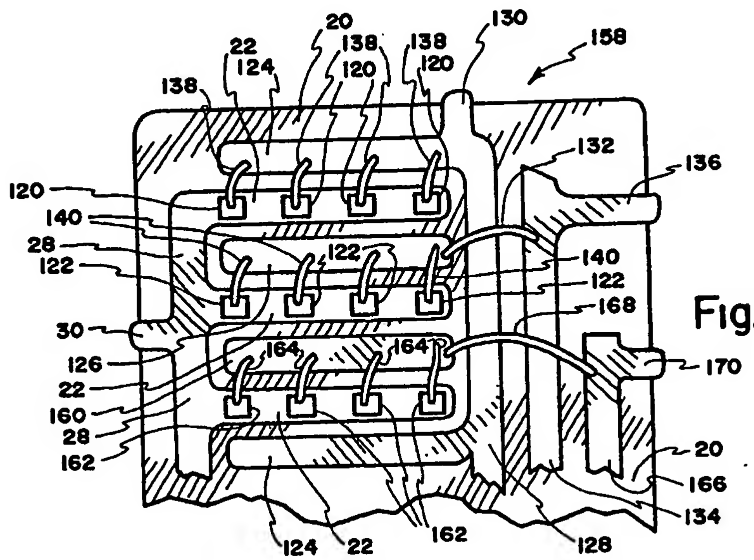


Fig. 6

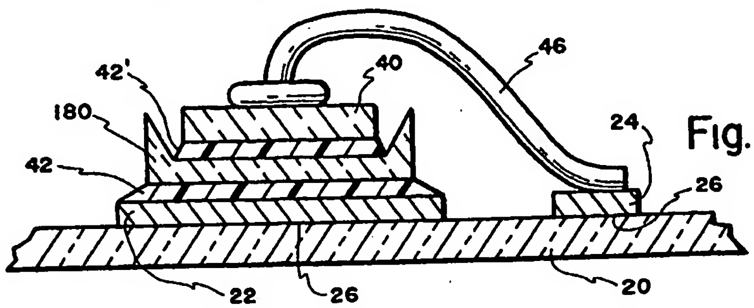


Fig. 15

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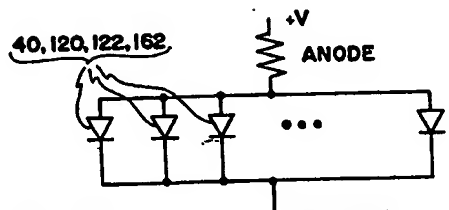

Fig. 8

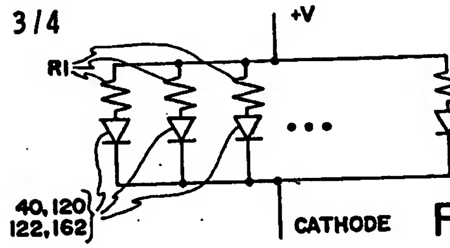

Fig. 9

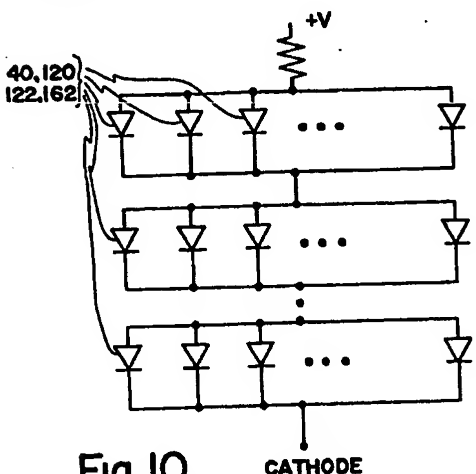

Fig. 10

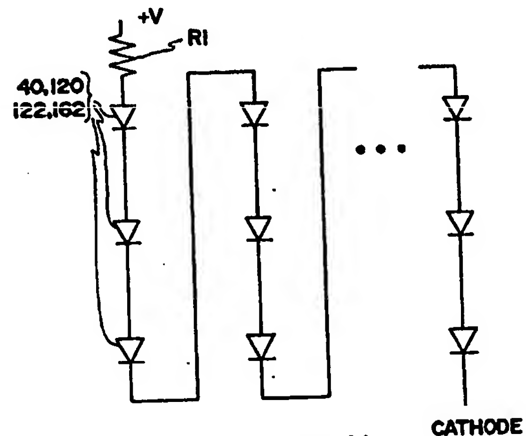

Fig. 11

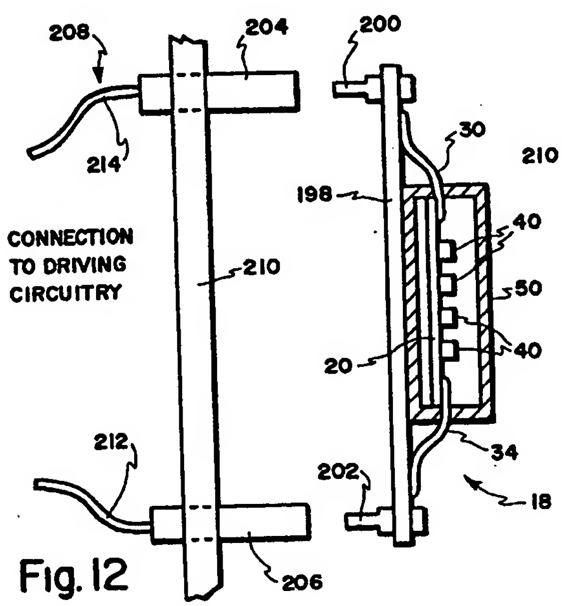

Fig. 12

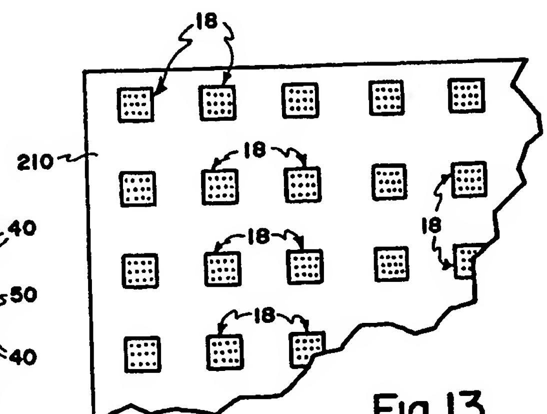

Fig. 13

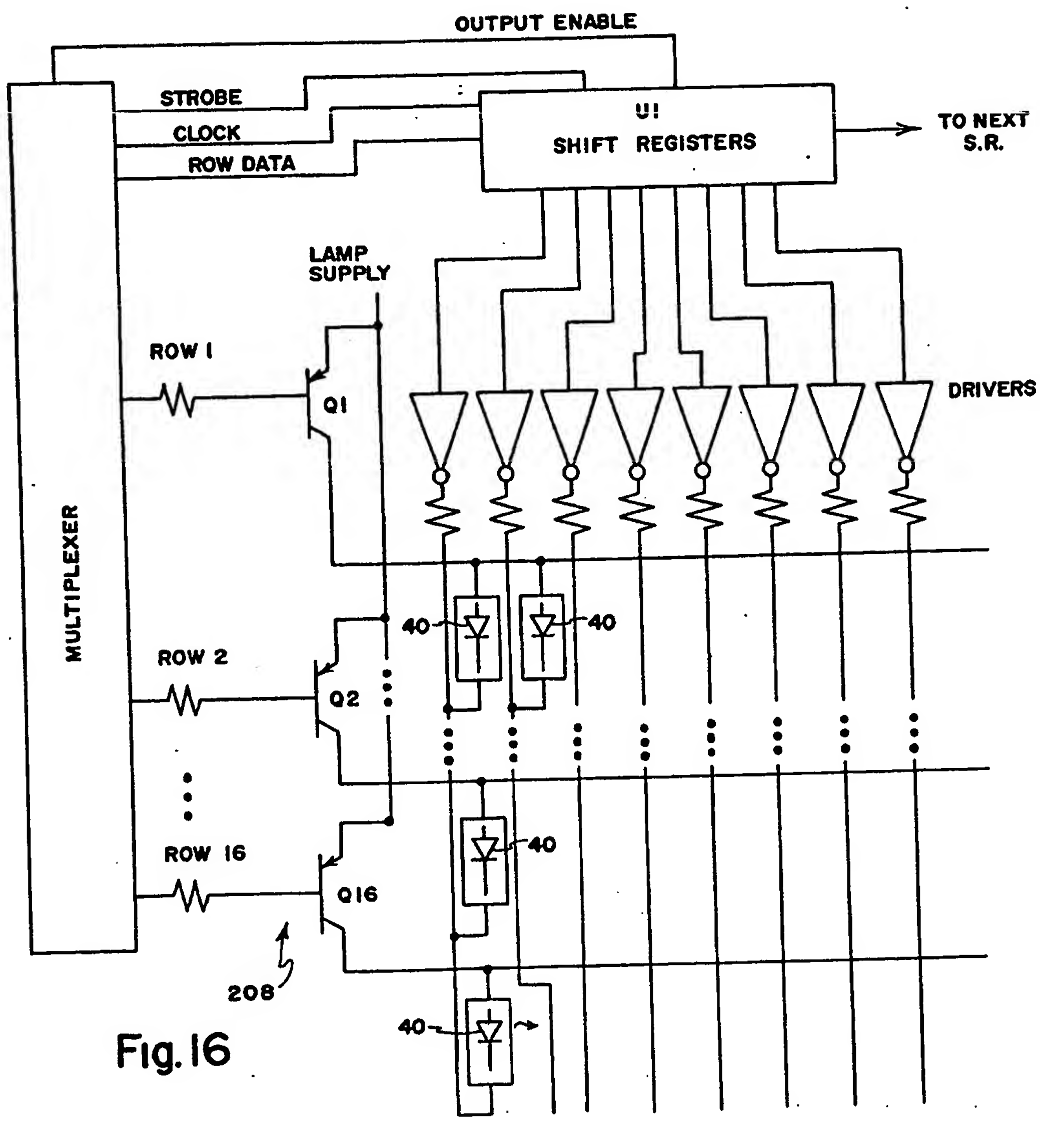
OUTPUT ENABLE
STROBE
CLOCK
ROW DATA
U1
SHIFT REGISTERS
TO NEXT S.R.
LAMP SUPPLY
ROW 1
Q1
DRIVERS
MULTIPLEXER
40
40
ROW 2
Q2
ROW 16
Q16
40
208
40

Fig. 16

SPECIFICATION

Electronic displays

This invention relates generally to display equipment and more particularly to a solid state display system suitable for a large monochrome and/or colour display, and to discrete light source elements therefor.

In the conventional construction of a large display system (for example baseball fields, apparatus for displaying advertising, pictures, or the like), the words or pictures are formed by selectively turning on or off coloured electric lamps in a predetermined pattern. Such display systems have presented many difficult problems.

The colour retention is poor, which results from the fact that the electric lamps bring out colours by having their filaments heated to red heat and assume a red heat or white orange colour. Therefore, in order to produce colours, coloured glass or glass plates are used to selectively filter the colour desired.

Since electric lamps on the order of 10 watts or more have been generally employed, a large display (which may include several thousand of such lamps) consumes a large amount of power and generates a large amount of heat.

A certain amount of time is required to turn on the electric lamps of such a display. Approximately 20 milliseconds are required for the filament to become heated to produce light and approximately the same amount of time to turn the filament off. This causes what is known as "trail off" as a picture or word is moved from one lamp to the next.

The expected life of such an electric lamp is of the order to 5000–8000 hours. Thus constant maintenance is required to replace lamps which have exceeded their useful life.

Heretofore, the use of LEDs in an outdoor display has been rejected as impractical. This has been due largely to the small amount of luminance available from the standard LED. The luminanace emitted by the 0.25 × 0.25 mm (0.625 square mm) LED chip is diffused over an area of approcimately 20 square mm; therefore the light is diffused over an area 300 times larger than the source chip and hence the actual light emitted is very low. This makes the discrete LED unreadable in direct sunlight.

According to a first aspect of the invention there is provided a light source element for a display system comprising an array of light emitting diodes for emitting light of at least one colour, anode and cathode conductors in respective electrical communication with the anodes and cathodes of the diodes, and means for energizing the diodes such that the light output of the or each colour of light emitted by the array exceeds 50 millicandela.

According to a second aspect of the invention there is provided a display matrix comprising a plurality of spaced light source elements, each element comprising an array of light emitting diodes; a source of low voltage electricity; and means for selectively communicating said electricity to at least some of the diodes of selected elements of the matrix to form a display.

The display systems may emit monochrome or coloured light, and may, for example, be used as scoreboards, message centres, and other large, intermediate and small display systems.

A large number of LED chips typically comprise each element and the element may be placed in a matrix and selectively illuminated under the control of driving circuitry. The light emitted is determined by the type of LEDs used in the array. Using three colours, blue, red, green that are controlled by separate driving circuitry any colour in the spectrum can be generated. Any type of LED may be used.

The electric lamp generally has an efficiency of up to 40 lumens/watt for converting electrical to optical energy. LEDs in accordance with the present invention have an efficiency of from 150 to 600 lumens/watts. Therefore, the LED array in accordance with the present invention has a better efficiency for converting electrical to optical energy by an order of magnitude.

The present LED array responds (turns on and off) much quicker, i.e. on the order of 10–20 nanoseconds which is a million times faster than the electric lamp. Another characteristic of the present LED array is its ability to respond to a pulse type of signal which allows the LED chip array to actually be turned on with a relatively low duty cycle, typically of the order of 6%. This results in a very low power consumption for the display.

The electric lamp has a relatively short life expectancy, commonly 5000–8000 hours. In contrast, the present LED has a life expectancy of 100,000 hours or greater. Replacement is seldom is ever needed.

With the array containing many LEDs spaced at closed intervals, the whole array may become a point source for the light; hence the effective light output per unit area is increased to the point that it becomes possible to have satisfactory contrast even when irradiated with sun in the daytime. The size of the array is determined by the number of LED chips included to achieve the size of element desired. It may commonly be desired to use an element which can generate a light source of sufficient luminance to be viewed in direct sunlight from distances of 300 to 600 feet or greater. To this end the light output (luminance intensity) per square metre—or luminance—of the or each colour of light emitted by the element should exceed 50 millicandela and may range up to, for

example, 100 candela, or more. Using LEDs presently available the minimum separation of LEDs within an element may for example be between 0.35 mm and 5 mm.

By using red, blue, green chip combinations on the same array with separate connecting leads, a true colour system is created which will reproduce any colour.

Preferably the light source elements can be used either in a new display or to retrofit existing displays.

A display system may be provided comprising discrete light source elements comprising an array of light emitting diodes having at least one of the following features: (1) all LED chips are of the same type connected in parallel, series-parallel, or series to produce images: (2) the LED chips comprise two or more colours, each separately electrically actuated accommodating change in the display image from one colour to another; and (3) the LED chips comprise red, green and blue colours, each colour being mounted as a group of LEDs in each array and each differentially electrially controlled to vary the intensity of the output of each colour whereby any colour in the spectrum may be selectively produced.

The invention will now be further described by way of example, with reference to the accompanying drawings, in which:

Fig. 1 is a side view elevation of an LED of an array in accordance with the present invention mounted on substrate;

Figure 2 is a front view of an LED array in accordance with the present invention;

Figure 3 is a side plan view of the LED array of Fig. 2;

Figure 4 is a plan view of an LED monochrome array mounted on substrate and showing electrical conductors;

Figure 5 is a side cross sectional view taken along lines 5–5 of Fig. 4;

Figure 6 is a plane view similar to Fig. 4, except an array arrangement of red, green and blue LEDs is illustrated;

Figure 7 is a plan view similar to Fig. 4, except an array arrangement of two different colours of LEDs is illustrated;

Figure 8 is a schematic representation of a parallel chip LED array;

Figure 9 is similar to Fig. 8, except a series-resistor is included for each LED of the array;

Figure 10 is similar to Fig. 8, except a series-parallel configuration is shown;

Figure 11 is similar to Fig. 9, except a series connection is shown;

Figure 12 is a side elevational view of a typical electrical connection arrangement for LED arrays in accordance with the present invention;

Figure 13 is a fragmentary plan view of a matrix display using LED arrays according to the present invention;

Figure 14 is a side elevation of an LED array according to the present invention encapsulated in a bulb with threaded fitting for retrofit utilization;

Figure 15 is a side elevation view similar to Fig. 1 further illustrating use of a reflective shield in conjunction with each LED of the array; and

Figure 16 is an electrical schematic of drive circuitry by which display systems in accordance with the present invention and specifically the LED arrays thereof are selectively controlled.

As mentioned heretofore, the actual dimensions of each discrete LED light source, generally designated 18, may vary Once the dimensions have been selected for a given display, an appropriately dimensioned substrate 20 layer is provided. In the illustrated embodiments, the substrate layer 20 is preferably a conventional dielectric ceramic upon which conductive areas are created using thin or thick film technology currently available. The elements may commonly be 12 mm to 110 mm across.

The utilization of such technology produces alternate cathode and anode conductive strips or fingers 22 and 24, respectively. The manner in which the conductive strips 22 and 24 are produced creates an integral bond at interface 26 (Fig. 1) between the substrate 20 and the conductive strips 22 and 24. The cathode conductive fingers 22 are joined electrically by a bridge 28 which terminates in an exposed conductive cathode connection terminal 30, in the monochrome embodiment 18 illustrated in Figs. 1, 4 and 5. Likewise, the anode conductive fingers 24 are electrically joined one to another by bridge 32 which terminates in an exposed conductive anode connection terminal 34.

Continuing the description of the monochrome embodiment 18, LED chips 40 are superimposed upon a layer of commercially available conductive expoxy 42 at predetermined spaced intervals 44 along each cathode conductive finger 22. In order to ensure that the illuminated LEDs of the array together appear to the observer as a point source of light, the LEDs are spaced such that the luminous intensity of the element when it emits light exceeds 50 millicandela. By definition a candela is a unit of luminous intensity or candle power equal to one lumen per steradian i.e. 1/16 of a square centimetre of area projected by a black body radiator at the solidification temperature of platinum. To achieve this, LEDs presently on the market will commonly be disposed in rows and columns which are successively spaced from one another by about 1.2 to 2.6 mm. After all LEDs are in place, the substrate is heated to a temperature sufficient to melt the conductive epoxy under each LED chip. After the conductive epoxy has cured, the chip is thereby bonded in place. A conductive wire 46 is then

connected from the anode of each LED chip to the adjacent common anode conductor or finger 24. The process of bonding each connecting wire or conductor 46 to the anode of each LED chip 40 and to the adjacent anode conductor 24 is well known and need not be described in this specification.

If greater light intensity is desired, a dish-shaped or concave LED reflector 180 (Fig. 15) of conductive material may be used at the back or cathode side of each LED. Conductive epoxy layers 42 and 42′ are used to secure the reflector 180 to cathode conductor 22 and to the cathode face of the LED, respectively.

It is presently preferred that each LED array 18 be encapsulated within a glass or plastic envelope at least the face of which is transparent. One such envelope is illustrated in Fig. 5 and comprises a filter lens 50 secured to the substrate 20 by bonding or the like at sites 52 and 54. The lens 50 keeps dirt and debris from reaching the LED array 18 thereby preserving a high degree of light transmission therethrough.

Another form of encapsulation is illustrated in Figs. 2 and 3 with the envelope again comprising transparent shape retaining synthetic resinous material which defines a front lens 56, top and bottom walls 58 and 60 (to which the substrate 20 is bonded at sites 62 and 64) and rear wall 66 which provides apertures 68 and 70 for conductors 72 and 74. The walls of the envelope 55 are integral one with another at corners 76. Conductors 72 and 74 are secured by soldering or the like to cathode terminal 30 and anode terminal 34, respectively. The described encapsulated arrangements are intended for use in new solid state display systems being fabricated from scratch.

In those cases where it is desired to retrofit an existing display system by replacing conventional discerete light source elements with discrete light source elements in accordance with the present invention, the configuration 80 of Fig. 14 may be used. Configuration 80 generally resembles a light bulb externally and comprises the previously described discrete LED light source element 18 enclosed within a transparent glass or plastic envelope 82 comprising a front lens 84, the substrate 20 of the discrete element 18 being secured to the envelope by bonding or the like at sites 86.

The glass or plastic envelope 82 is necked down at site 88 and there receives a conventional threaded conductor 90. Male threaded conductor 90 is sized and shaped so as to be capable of being electrically threaded into an existing display system to replace a conventional light source. Conductors 92 and 94 conventionally connect to the threaded collar 96 of the fitting 90 and the central ground conductor 98 also of the male fitting 90 whereupon electricity of relatively high voltage is communicated to transformer 100 contained within the envelope 82. Transformer 100 reduces the voltage of electricity to a level compatible with the LEDs of the discrete element 18 which low voltage electricity is communicated along conductors 102 and 104 to a current limiting diode bridge 106 and from thence along previously described conductors 72 and 74 to discrete light source element 18.

Reference is now made to Fig. 7 which illustrates a two colour or combination monochrome embodiment of the present invention. The discrete LED light source element of Fig. 7 is generally designated 118. Discrete element 118 is identical or substantially identical in certain respects to the previously described discrete element 18. Those parts of discrete element 118 which are common to previously described parts of discrete element 18 have been so numbered and no further description thereof is deemed necessary at this point. Discrete element 118 is formed in a fashion and of materials as heretofore described in conjunction with discrete element 18.

Discrete element 118 utilizes alternating rows of red LEDs 120 and green LEDs 122. Red and green LEDs have been chosen arbritrarily and, therefore if desired, other colours can be used. LEDs 120 and 122 are secured in the illustrated positions as heretofore described at close intervals as mentioned previously.

Also provided are red LEDs anode conductive fingers 124 and green anode conductive fingers 126. As can be seen from inspection of Fig. 7, every other anode conductor interposed between cathode conductors comprises red anode conductor 124 and green anode conductor 126. The red anode conductive fingers or strips 124 are commonly joined by a conductive bridge 128 which provides a red anode conductive terminal 130. The green anode conducting fingers or strips 126 are respectively joined by conductors 132 to a green anode conductive bridge 134, which comprises a green anode conductive terminal 136. Further in respect to discrete element 118, the anode of each red LED is connected to the adjacent red anode conducting strip 124 by a looped connecting wire or conductor 138. By the same token, the anode of each green LED is connected by a connecting wire or conductor 140 to the adjacent green anode conducting strip 126.

Discrete element 118 may be encapsulated in any satisfactory way including but not limited to the aforementioned ways to provide an encased discrete element for installation in display systems being newly created or for retrofit purposes in existing display systems.

As can be appreciated, when no electricity whatever is delivered to any of the conductive strips of discrete element 118, the visual

appearance of the element is dark. When low voltage electricity is communicated at the red anode conducting fingers 124, the discrete element 118 displayed light having a red hue or colour, the illuminated LEDs of the element has the appearance to an observer of being a point light source. When electricity is delivered to the green anode conducting fingers 126, the green LEDs become luminous causing the viewer to see the colour green as a point source of light. If both the red and green LEDs are illuminated simultaneously, a third colour will result, the hue of which may be varied depending upon the nature of electrical power delivered to the red and green LEDs, respectively.

Reference is now made to Fig. 6 which illustrates an infinite colour discrete LED light source element, generally designated 158. Those portions of discrete element 158 common to previously described discrete element 118 are correspondingly numbered and no further description is here deemed necessary.

At every third gap between cathode conducting strips 22 is disposed a red anode conductive strip 124, a green anode conductive strip 126 (both heretofore disclosed) and a blue anode conducting strip 160, respectively. Every third cathode conducting strip 22 respectively conductively supports red, green and blue LEDs 120, 122 and 162 at predetermined intervals as heretofore mentioned. At every third conducting finger 22 is disposed a plurality of spaced blue LEDs 162 in electrical communication with the adjacent blue anode conducting finger 160 via connecting wires or conductors 164. Each conducting strip 160 is in electrical communication with a conducting bridge 166 by a connecting wire or conductor 168. Bridge 166 comprises anode connection terminal 170.

It should be readily apparent that by selectively controlling electricity delivered to the red, green and blue LEDs and controlling the magnitude thereof, the discrete element 158 may either be dark or consist of any colour within the spectrum at any desired point in time.

Notwithstanding the heretofore described connections to the various LEDs, it is to be appreciated that each discrete LED light source array in accordance with the present invention may be connected in parallel, in series-parallel and in series as illustrated in Figs. 8, 10 and 11. For causing each LED which is illuminated to have uniform brightness, a resistor R1 is used in series with the anode of each LED, as shown in Fig. 9.

The operation of an LED, including light generation and the output luminance are well known and will not be treated here. The operation of LED arrays in accordance with the present invention is discussed hereinafter.

Each LED in the array, when illumination is desired, is pulsed with approximately 200 milliamperes of current for a duration of essentially 200 microseconds with a duty cycle of six percent (6%) or less. The amount of current supplied to the LED array is determined by the size of the array and the number of LEDs. Therefore, the size and thickness of the conductors used on the substrate are selected to be capable of handling the current pulses without adding excessive resistance or degrading the conductor. Sufficient heat sink to dissipate the heat thereby maintaining temperatures that are in an acceptable range for proper LED operation is also important.

Referring to Fig. 8, applying a pulse of +8 volts to all or some of the LEDs of the array will cause the LEDs to illuminate. The amount of luminance of the array is determined by the number of LEDs illuminated in the array. If equal output or intensity of each LED is desired, a resistor R1 is placed in series with the LED, causing uniform brightness of each LED. See Fig. 9.

When the number of LEDs in the array reaches a practical limit for heat dissipation, a series-parallel circuit, as shown in Fig. 10, can be utilized to further increase the number of LEDs in the array. In this way, the total current density is decreased by the amount of parallel banks of LEDs in series. For example, if 64 LEDs were used, a pulse current of 12.8 amperes is needed with the circuitry of Fig. 8. If array were divided into four banks of 16 LEDs and connected in series, as illustrated in Fig. 10, the total current required would be reduced by 3/4, i.e. to 3.2 amperes. However, the applied voltage would have to be increased by four times. Once again, if uniform output is required, a resistor R1 is needed.

For those applications where a very low current is needed and a high voltage is available, the LEDs in the array can be in series as shown in Fig. 11. Here, the current can be pulsed at the 200 millamperes or the current reduced at 20 millamperres and applied in a continuous manner.

Reference is now made to Figs. 12 and 13 which show presently preferred structure for connecting the discrete LED light source arrays 18 to driving circuitry. Specifically, each array 18 is equipped with conductive pins 200 and 202 mounted to backing 198 and respectively electrically connected to the cathode and anode terminals 30 and 34.

Pins 200 and 202 are aligned with and are releasably press fitted into female electrical receptacles 204 and 206 of the driving circuitry 208. Female receptacles 204 and 206 are firmly carried by a mounting display board 210. Thus, the cathode of each LED 40 of element 18 is electrically connected to pin 202, fitting 206 and wire 212 of the driving circuitry. The anode of each LED 40 of element 18 is electrically connected to pin 200, fitting 204 and wire 214 of the driving cir-

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cuitry.

When all of the elements 18 of a given display system have been mounted to the board 210, as described, the display configuration of Fig. 13 is created.

Typical matrix driving circuitry 208 is shown in Fig. 16. In operation, the data of Row 1 is clocked into the bit one register of shift register U1 on the positive transition of the clock pulse. On the next positive transition of the clock pulse the first data bit is shifted one position to the right and the next bit is entered into bit one register. Data is continued to be shifted and entered until 256 data bits have been entered and, therefore, all of Row 1 data is now contained in the U1 shift registers. After the 256th bit has been entered, the multiplexer generates a positive STROBE pulse which transfers the data in the shift registers to the storage registers of U1. The OUTPUT ENABLE signal is enabled by a high level logic signal as long as data is being sent by the mutliplexer and, thus, the data in the storage registers appear at the outputs of U1 and are applied to the driver U2 which either apply a ground or lamp supply to the anode of Row 1 LED arrays. At the same time the Strobe Signal appears, a counter in the multiplexer is incremented and a logic low Row 1 signal is generated which turns on Q1 transistor and applies lamp supply to all the LED array in Row 1. During the time that Row 1 is "on", data for Row 2 is next clocked into the shift registes and after 256 data bits have been shifted in, a strobe pulse is generated to transfer data to the storage registers again presenting data to drivers U2. At the same time, the counter has been incremented to "turn off" Row 1 and "turn on" Row 2. This same procedure continues until all 16 Rows have been turned "off" and "on". Then the procedure starts all over with Row 1. The "on" time for each row is approximately 200 microseconds.

Since a large amount of current is drawn only during six percent (6%) of the time, the effective or average power consumption is decreased remarkably.

CLAIMS

1. A light source element for a display system comprising an array of light emitting diodes for emitting light of at least one colour, anode and cathode conductors in respective electrical communication with the anodes and cathodes of the diodes, and means for energizing the diodes such that the light output of the or each colour of light emitted by the array exceeds 50 millicandela.

2. An element according to claim 1 wherein the separation of the diodes in the or each direction in which they are most closely spaced does not exceed 5mm.

3. An element according to claim 1 or 2 wherein the separation of the diodes in the or each direction in which they are most closely spaced exceeds 0.35 mm.

4. An element according to any preceding claim in which the light output of the or each colour of light emitted by the array does not exceed 100 candela.

5. An element according to any preceding claim in which the width of the element exceeds 1cm.

6. An element according to any preceding claim wherein the width of the element does not exceed 12 cm.

7. An element according to any preceding claim wherein the diodes of the array emit light of a single colour.

8. An element according to any of claims 1 to 6 wherein the array comprises at least two sets of light emitting diodes, each set emitting light of a different colour.

9. An element according to claim 8 wherein the anodes of each set of diodes are connected to different anode conductors and the cathodes of the diodes of the element are connected to the same cathode conductor.

10. An element according to claim 8 or 9 wherein the array comprises three sets of diodes, each set emitting light of a different primary colour.

11. An element according to any of claims 8 to 10, wherein control means is provided to actuate the sets independently of each other, to control the colour of the light emitted by the element.

12. An element according to any preceding claim, wherein each light emitting diode is associated with reflector means.

13. An element according to claim 12 wherein a reflector of conductive material is disposed behind each diode, connected between the cathode of the diode and the cathode conductor.

14. An element according to any preceding claim wherein the element is at least partially enclosed by a rigid housing which has a transparent face.

15. An element according to claim 14, further comprising a standard electrical fitting electrically connected to the anodes and cathodes of the diodes across a transformer and a current limiting diode bridge, whereby the element may be retrofitted in an electric socket of a conventional light source.

16. An element according to any preceding claim wherein at least some of the anode and cathode conductors are deposited on a dielectric substrate as a printed circuit board.

17. An element according to any preceding claim wherein the cathode and anode conductors each comprise a plurality of conductive strips, the cathodes of the diodes being bonded to the cathode strips and the anodes of the diodes being connected to the anode strips by conductive wires.

18. A display system comprising:

a display matrix comprising a plurality of

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spaced light source elements, each element comprising an array of light emitting diodes;

a source of low voltage electricity;

and means for selectively communicating said electricity to at least some of the diodes of selected elements fo the matrix to form a display.

19. A display system as claimed in claim 18, wherein the light source elements are as claimed in any of claims 1 to 17.

20. A light source element substantially as hereinbefore described with reference to the accompanying drawings.

21. A display system substantially as hereinbefore described with reference to the accompanying drawings.

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